Validation and comparison of numerical wind atlas methods: the South African example

Hahmann, Andrea N.; Badger, Jake; Volker, Patrick; Nielsen, Joakim Refslund; Lennard, Chris; Hansen, Jens Carsten; Mortensen, Niels Gylling

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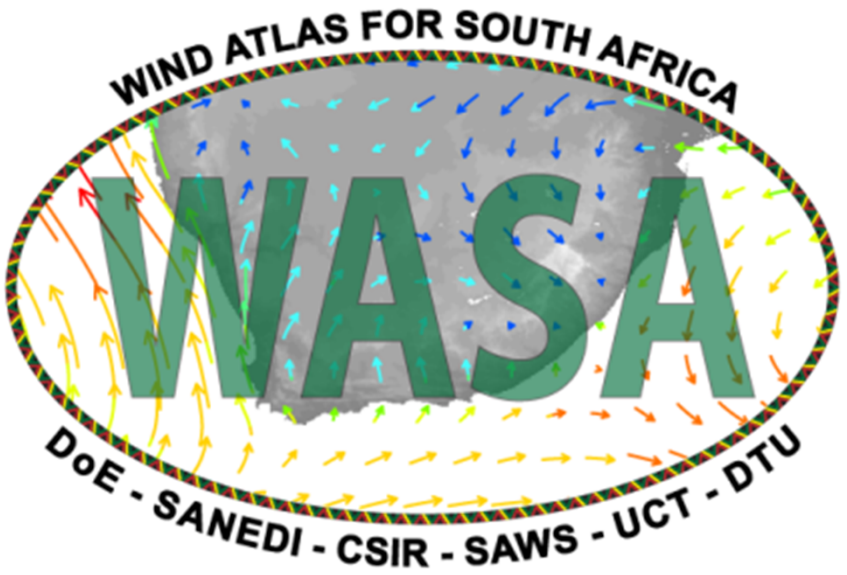
Andrea N. Hahmann[1], Jake Badger[1], Patrick Volker[1], Joakim Refslund[1], Chris Lennard[2], Jens Carsten Hansen[1], Niels Mortensen[1]

[1] DTU Wind Energy, Risø Campus, Roskilde, Denmark

[2] University of Cape Town, Cape Town, South Africa



DTU Wind Energy
Department of Wind Energy

Outline

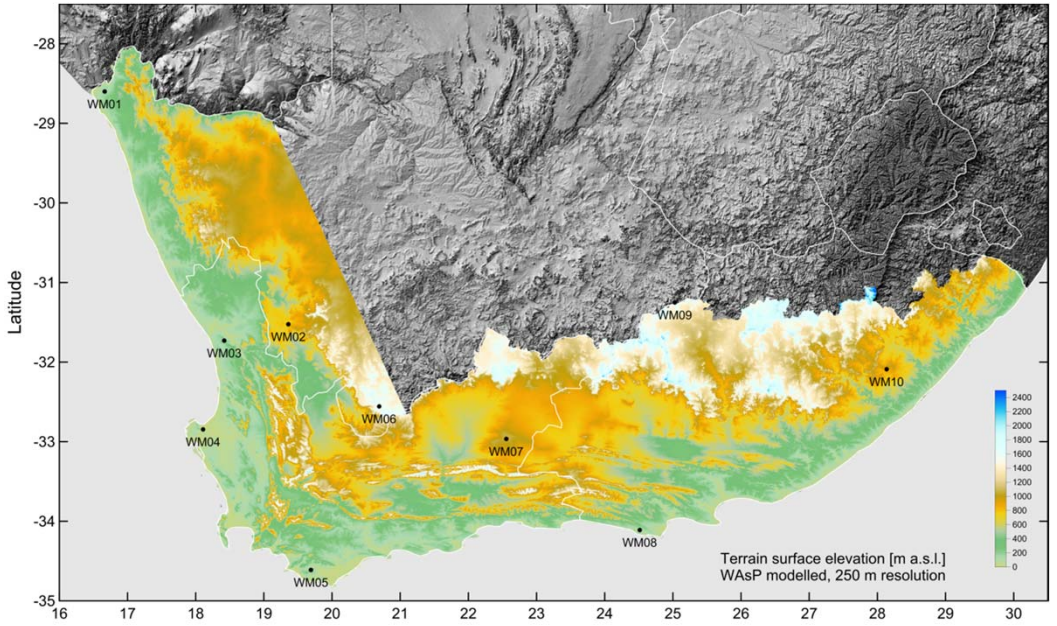
- Introduction to the WASA project
- Downscaling methods
  - KAMM/WAsP
  - WRF-based
- Microscale modeling at verification sites
- Generalization procedure
- Validation and comparisons
- Conclusions

The Wind Atlas for South Africa (WASA) Project

- Objectives: to develop, verify and employ numerical wind atlas methods and to develop capacity to enable large scale of exploitation of wind energy in South Africa.
- The project includes:
  - 10 measurement masts (top anemometer 62 meters); most sites operating September 2010 – present (data freely available: http://wasadata.csir.co.za/wasa1/WASAData)
  - Two numerical wind atlas; preliminary statistical-dynamical downscaling (KAMM/WAsP); final WRF-based dynamical downscaling
  - wind resource assessment and siting tools for planning purposes that can be used for feasibility studies in support of projects.

First preliminary wind atlas made available in 2012

The (WRF-based) atlas will be freely available to all interested parties on the completion of the project (31 March 2014)



What is the difference between the KAMM and WRF numerical wind atlases?

Statistical-dynamical method
KAMM-based (1st wind atlas)

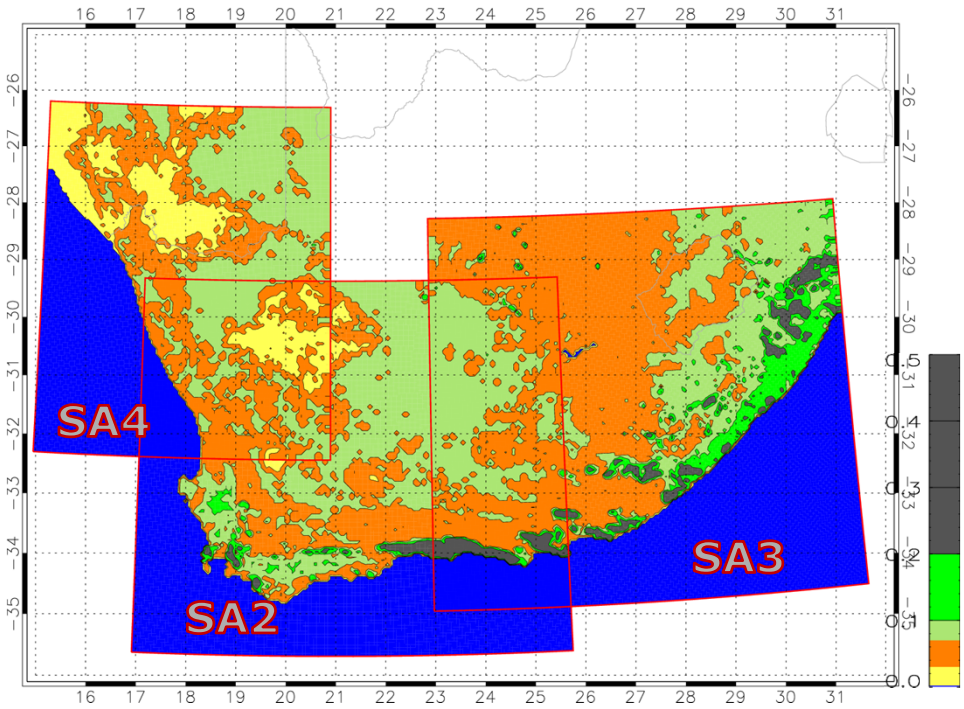
- "steady-state" simulations from 100+ wind situations (sets of initial conditions)
- each initialized with a single vertical representation of the atmosphere
- lower boundary conditions: uniform land and sea temperatures

Dynamical downscaling
WRF-based (WASA phase 2)

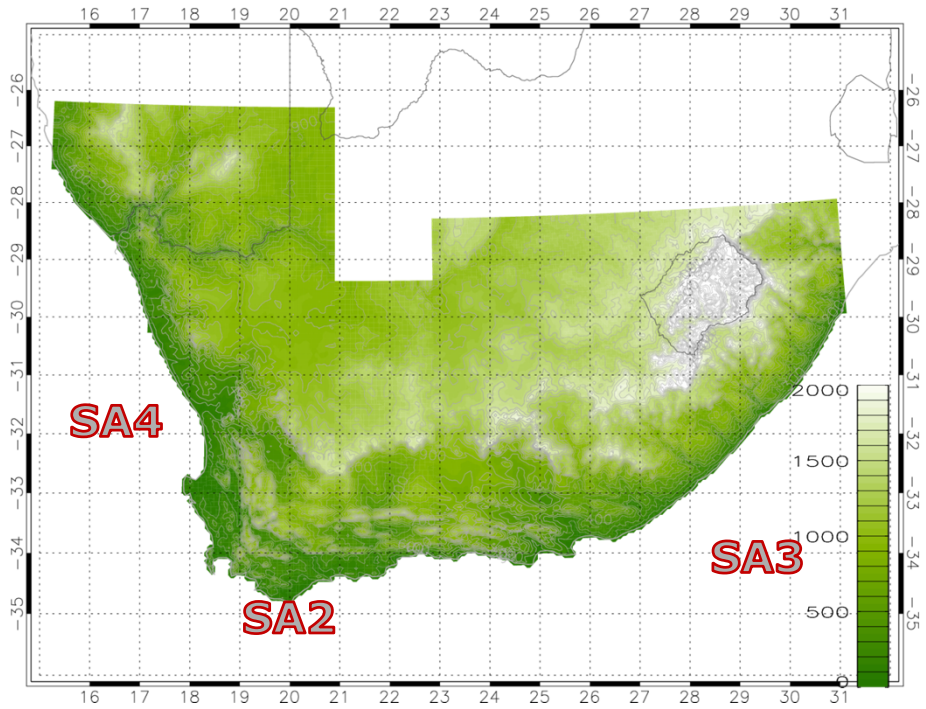
- "sequential" simulation that provides time-series for each grid point in the domain
- initialized with a 3 dimensional state of the atmosphere
- lower boundary conditions: interactive land + time-varying sea surface temperatures

KAMM-based simulation

surface roughness

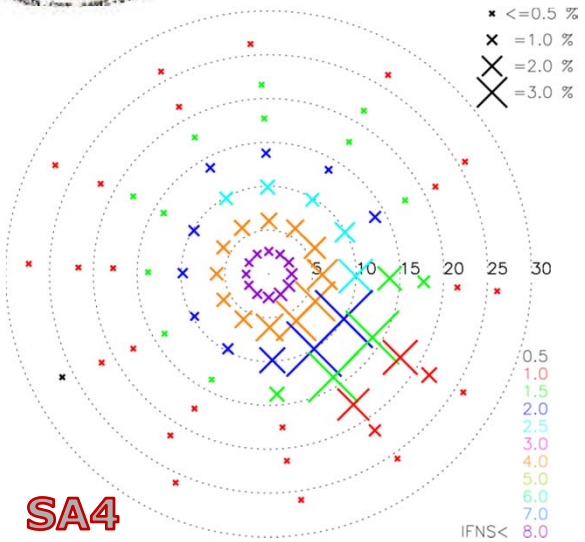


surface elevation



3 separate domains, 5 km grid spacing

Meteorological forcing – KAMM simulations



SA4

West domain

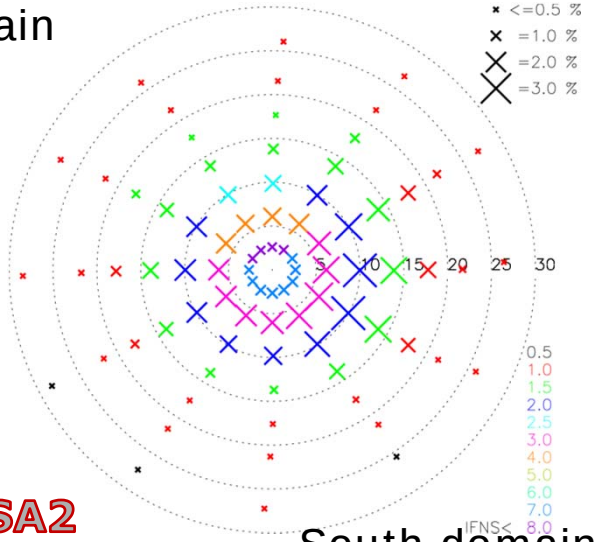
Forcing profile described at
0 m, 1500 m, 3000 m, 5500 m

0 m winds shown

- each x indicates a different forcing of the mesoscale model
- frequency of occurrence of each wind varies within domain

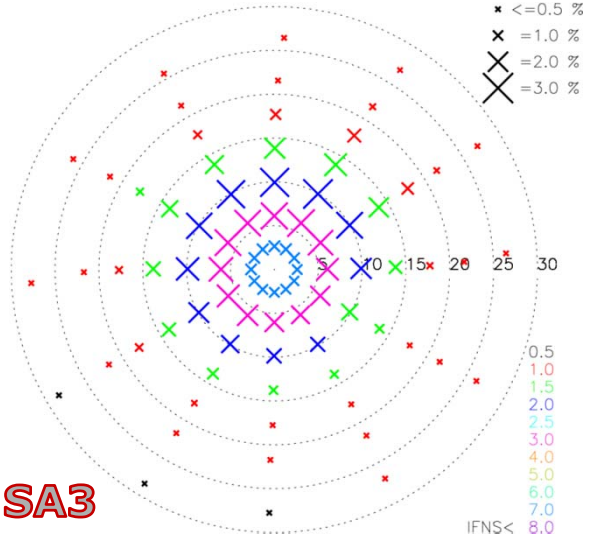
Polar plots:

- Angle – wind direction
- Distance – wind speed
- Frequency – size of cross
- Stability – color of cross



SA2

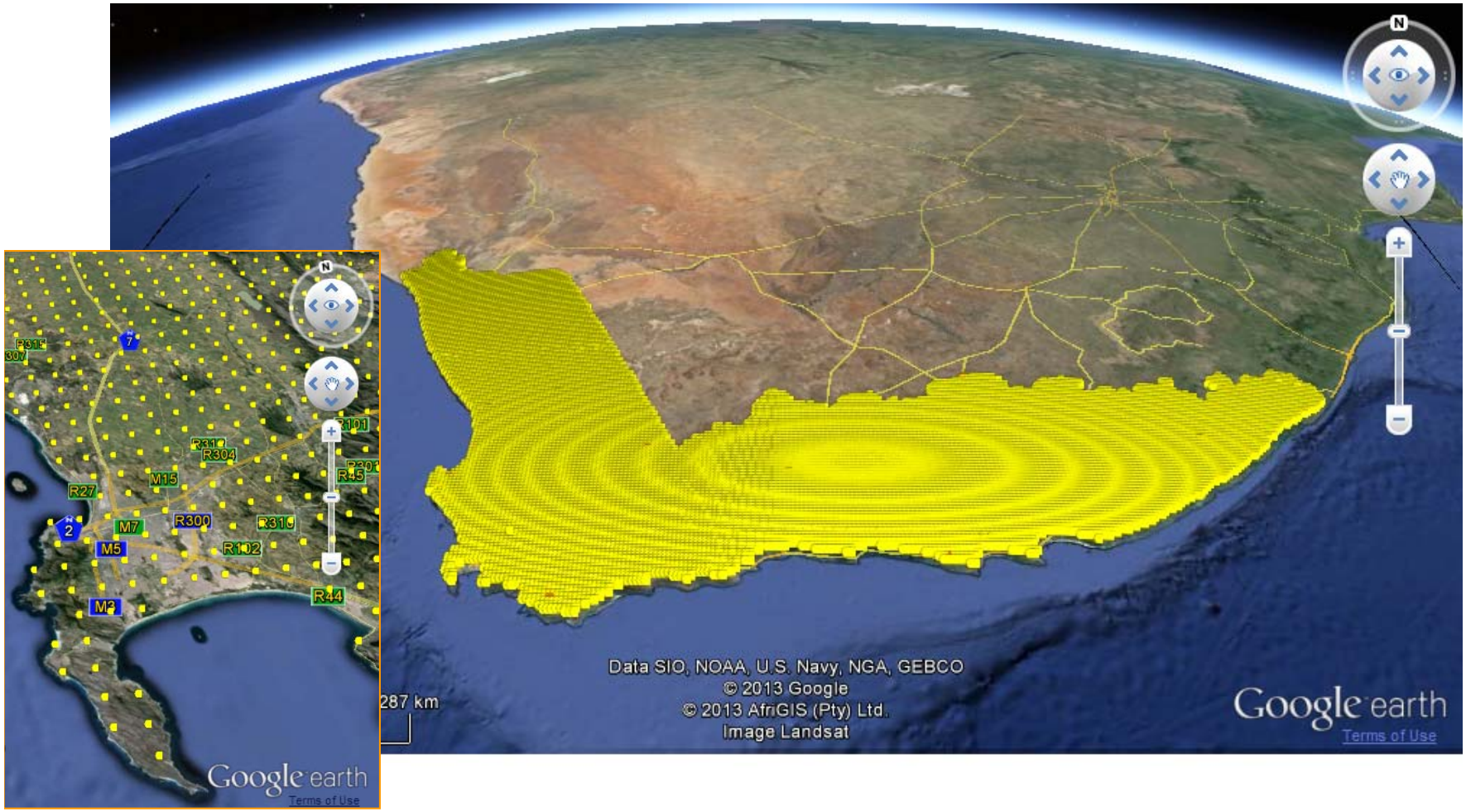
South domain



SA3

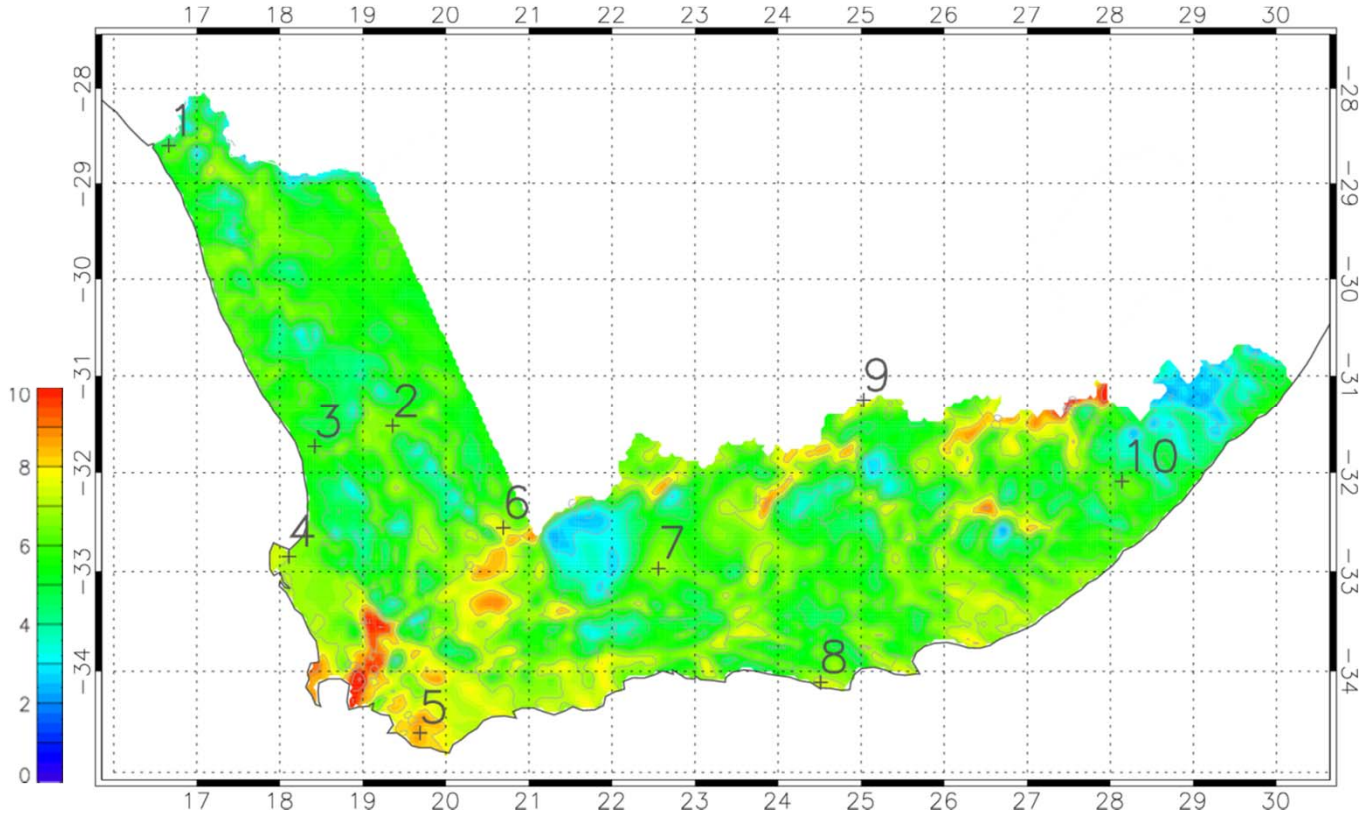
East domain

First Verified Numerical Wind Atlas 2012



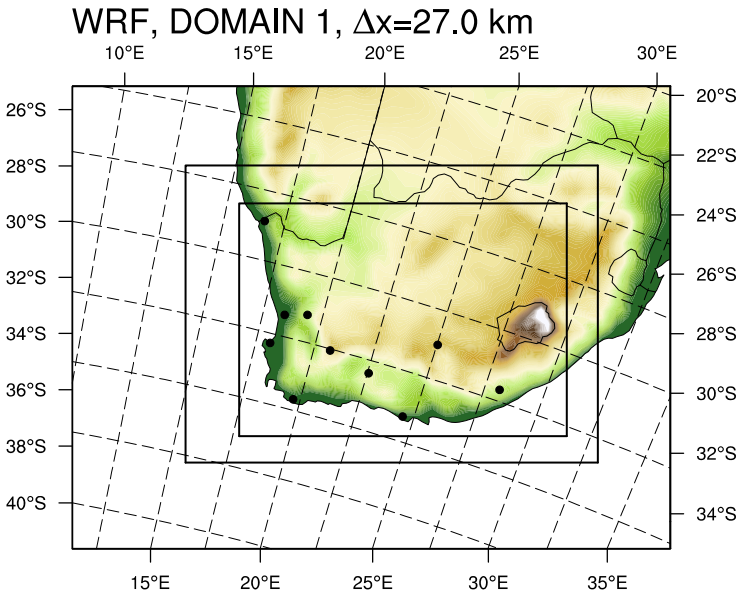
Verified Numerical Wind Atlas for South Africa
VNWA launched March 2012

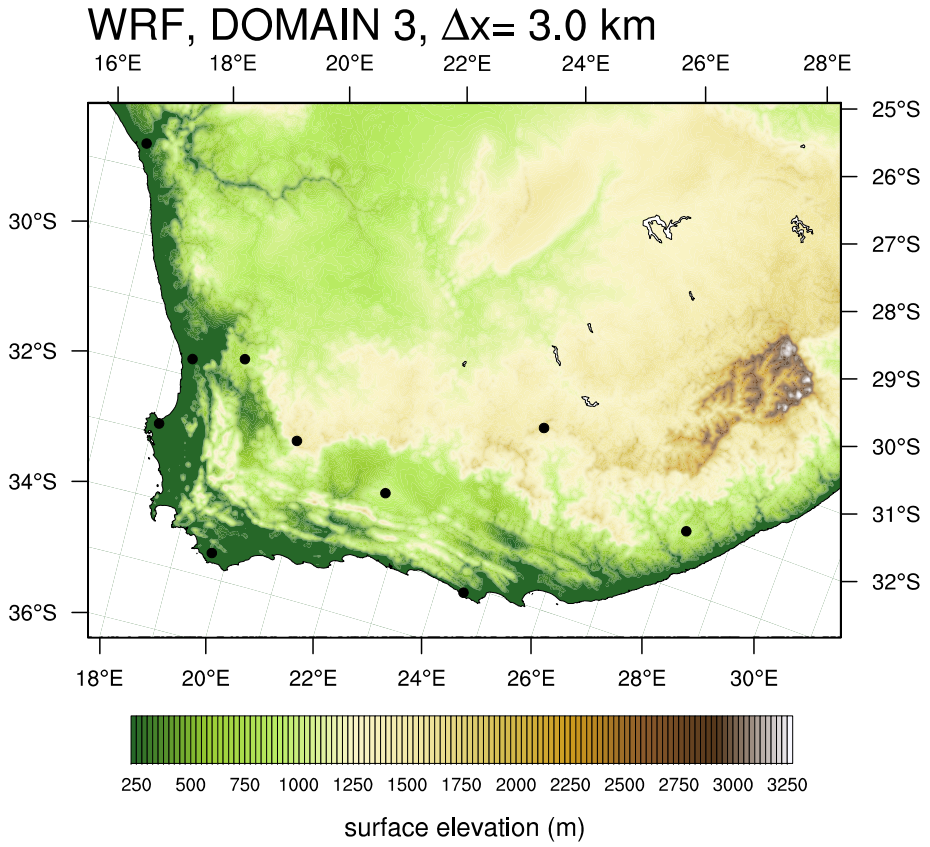
- the KAMM/WAsP method
- verified against 1 year of data
- a map – and much more



Generalized climatological (30-year) annual mean wind speed [m/s] 100 m above ground level, flat terrain, 3 cm roughness everywhere

WRF Model Configuration





Very large (309 x 435) inner grid (3km grid spacing)

Changes to standard WRF land use and roughness

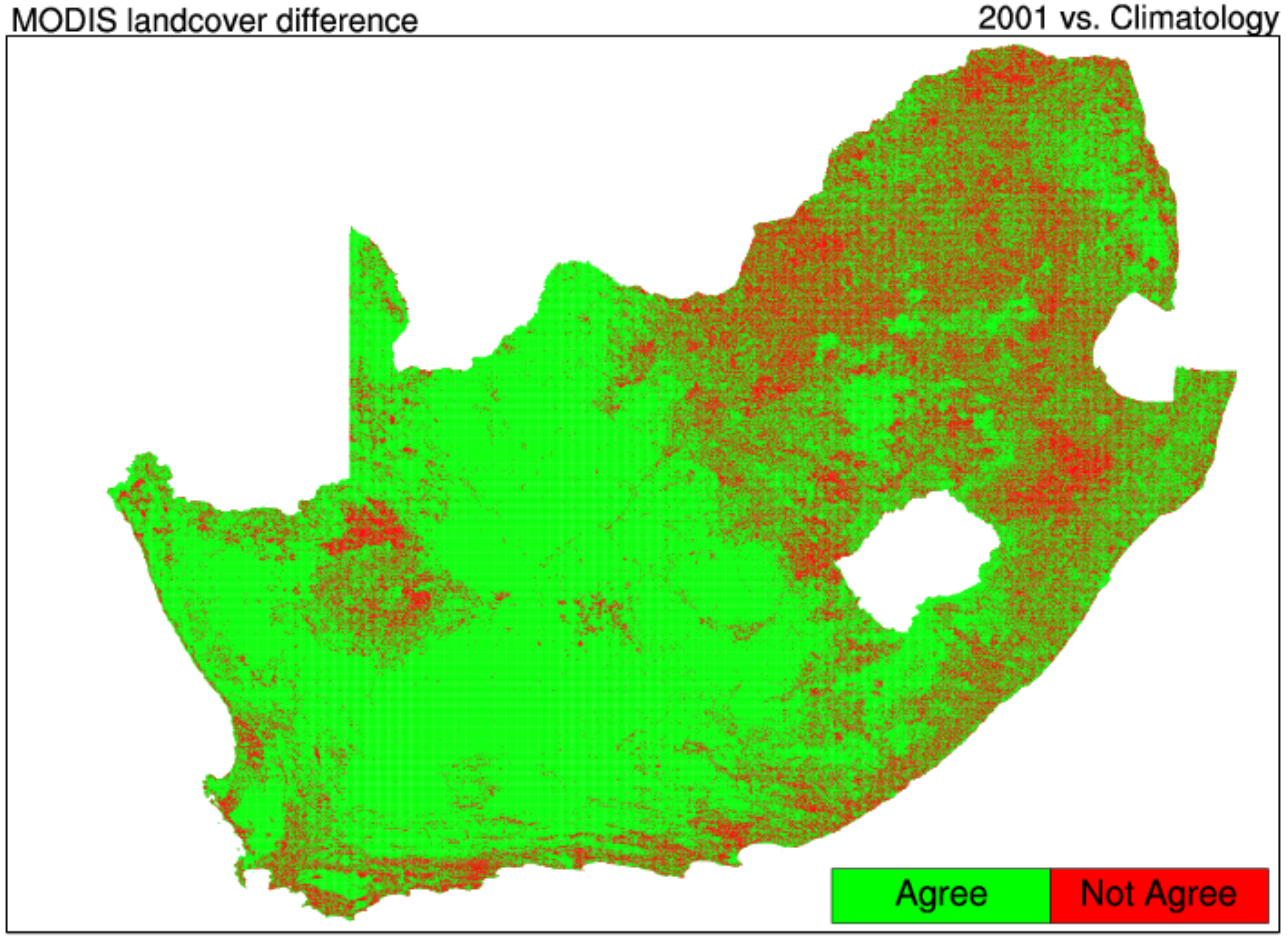
Simulations: 8 years for (27/9/3 km);
24 years (27/9 km)

ERA-Interim forcing, 1/12 degree SSTs; MYJ PBL; 41 vertical levels

Extensive set of year-long simulations were performed to optimize domain size and location and various parameterizations.

Very little sensitivity to most of these, except for the grid configuration (size, grid spacing, location)

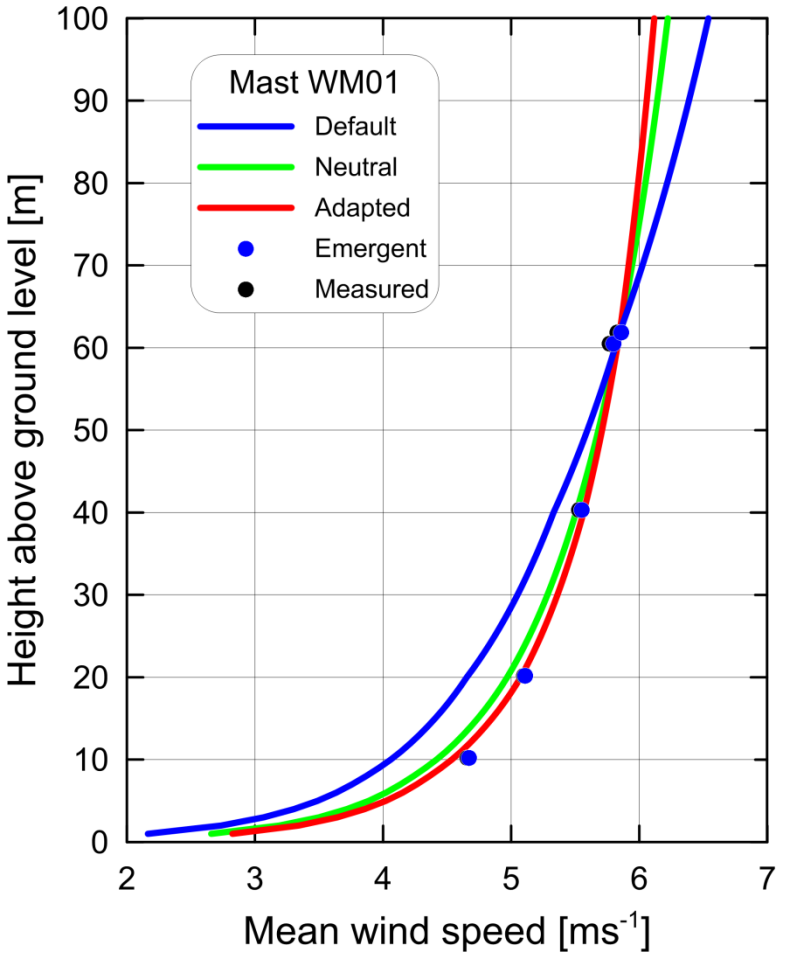
Difference in MODIS Landcover



Difference in land cover classes between what is currently used in WRF and the new MODIS climatology (2001-2012)

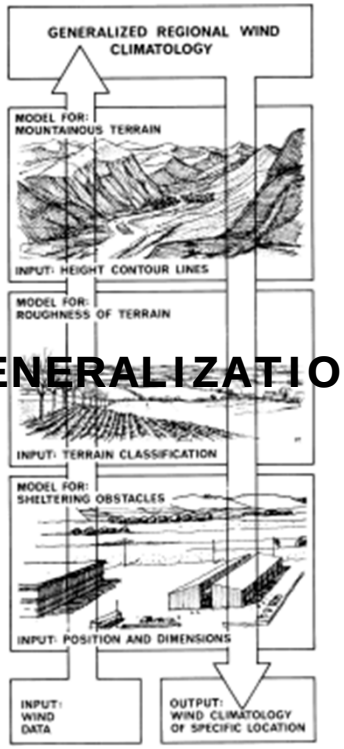
Microscale modelling at the 10 WASA masts
Some background

- Wind-climatological inputs
  - Three-years-worth of wind data
  - Five levels of anemometry
- Topographical inputs
  - Elevation maps (SRTM 3 data)
  - Simple land cover maps (SWBD + Google Earth); water + land
- Preliminary results
  - Microscale modelling verification
    - Site and station inspection
    - Simple land cover classification
    - Adapted heat flux values
  - Wind atlas data sets from 10 sites

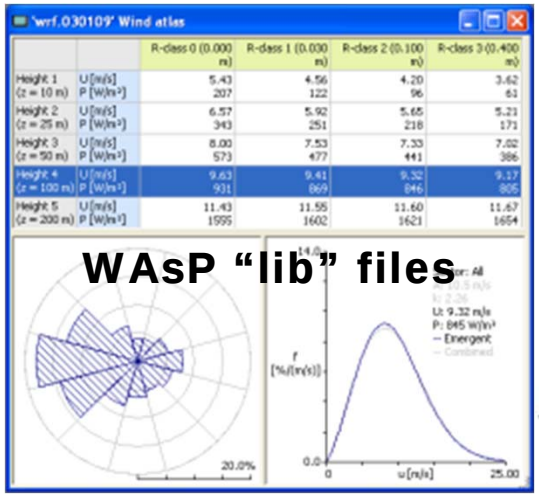


Validation after generalization

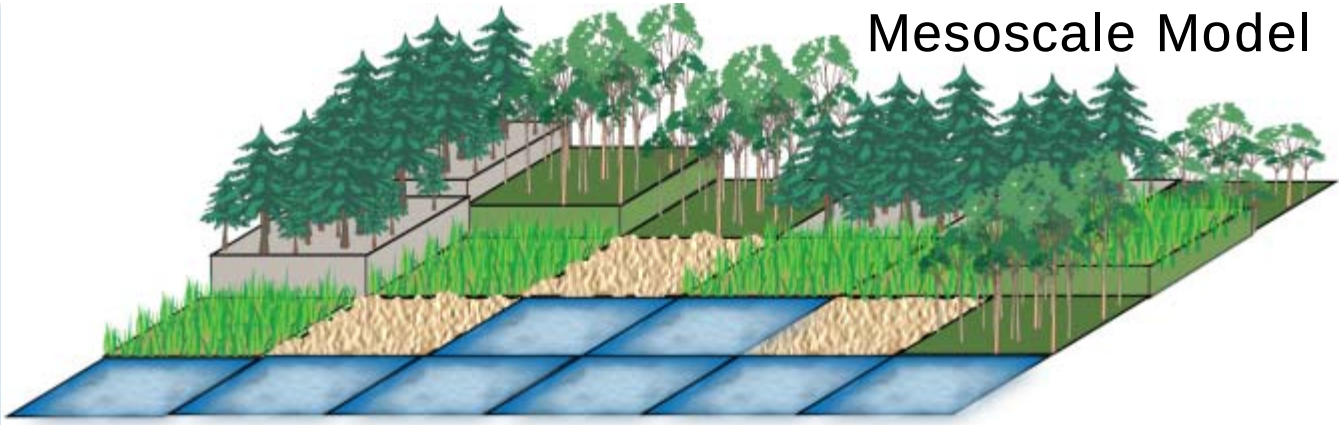
Photo: Forskningscenter Risø



GENERALIZATION

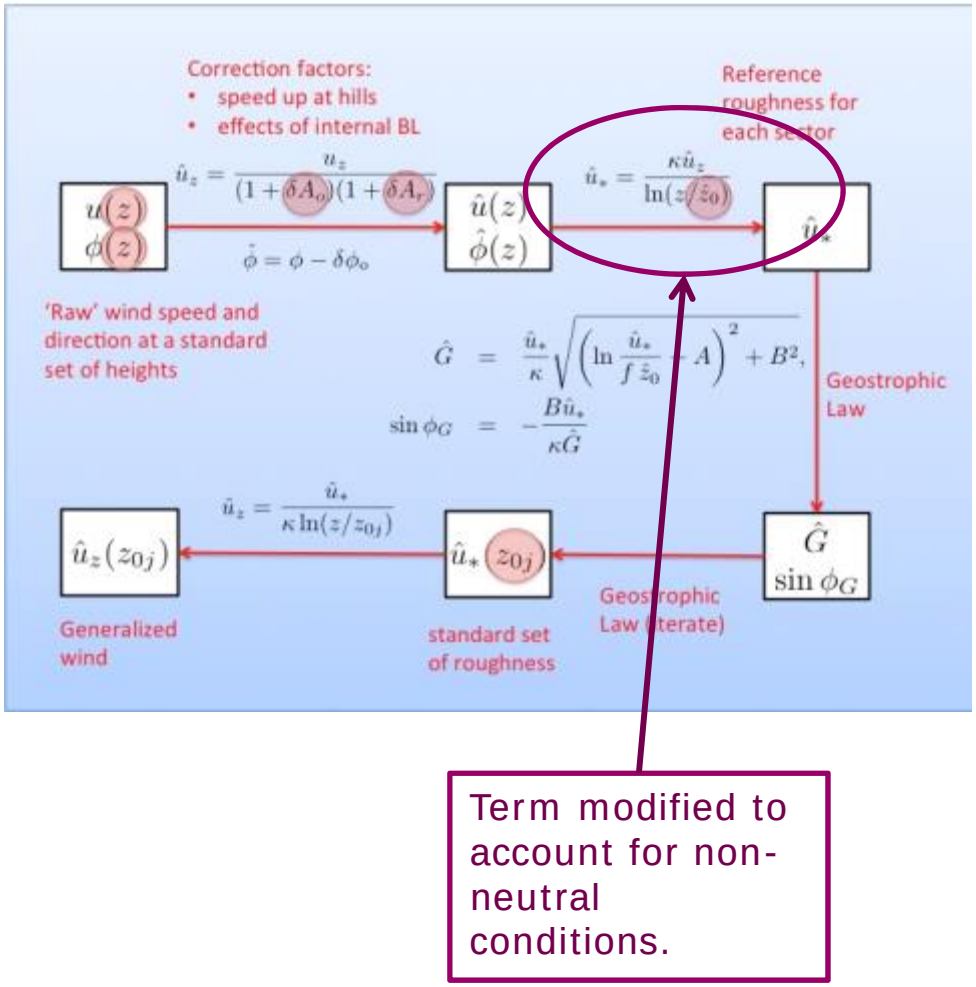


WAsP "lib" files



Mesoscale Model

Mesoscale generalization procedure



Similar generalization procedure for KAMM and WRF simulations.

In KAMM – generalization applied to the results of the simulations for each wind class (under neutral assumption)

In WRF – results from simulations are binned according to wind direction, wind speed, and stability (1/L).

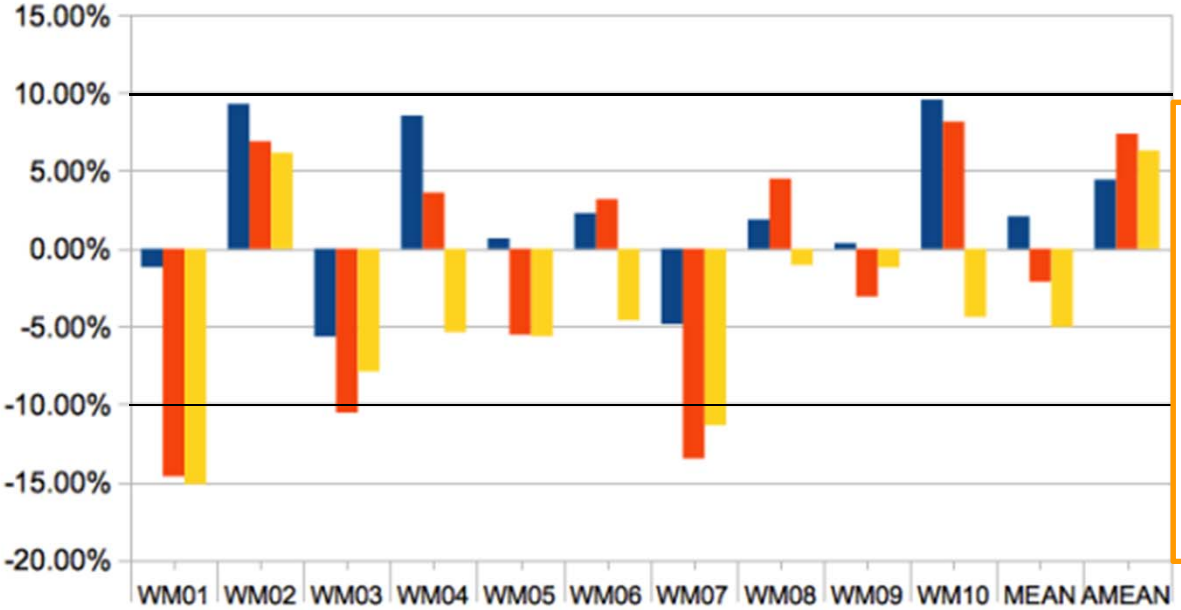
Each binned wind class is then generalized and aggregated using their frequency of occurrence

Neutral or non-neutral assumption was tested

Verification at WASA Masts

Numerical wind atlas (NWA) compared to observational wind atlas (OWA) Generalized annual mean wind speed at 100 m, z0 = 3 cm [m/s]

Error=$(U_{model}-U_{obs})/U_{obs}$, U=long-term mean wind speed



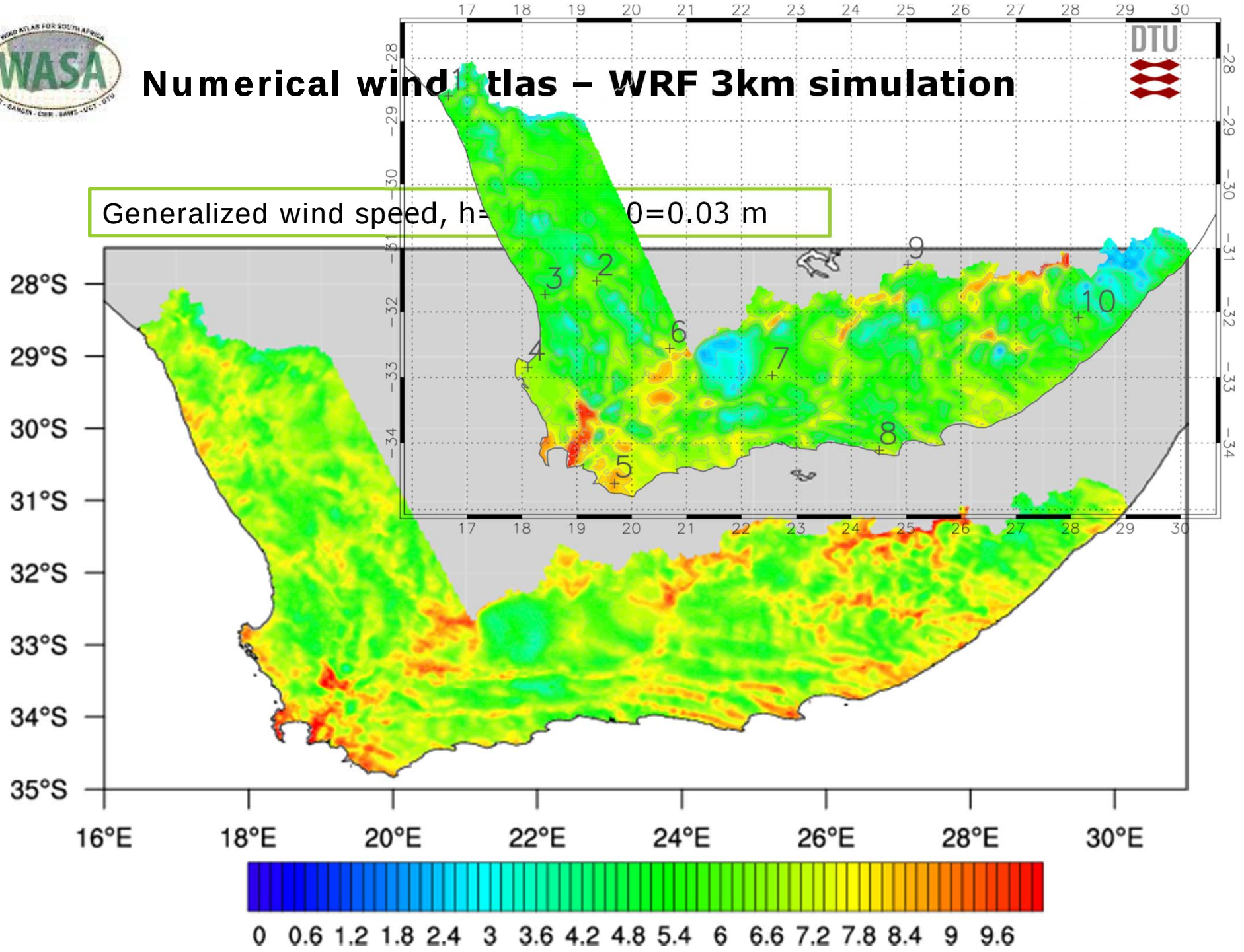
WRF-based
Non-neutral (4.4%)
Neutral (7.8%)

KAMM-WAsP (6.4%)
(based on two years of data)

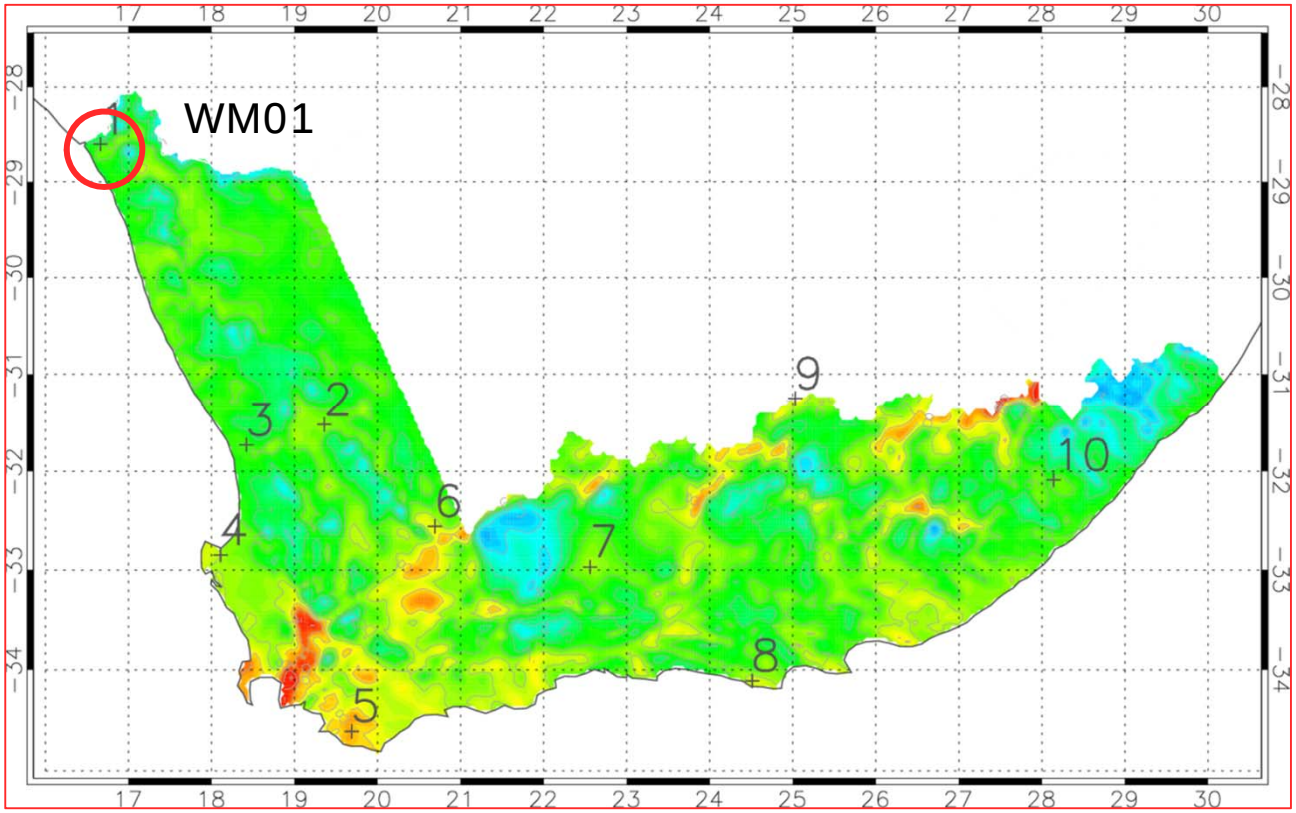
Verification site

Absolute Mean

Numerical wind atlas – WRF 3km simulation



Comparison at specific sites

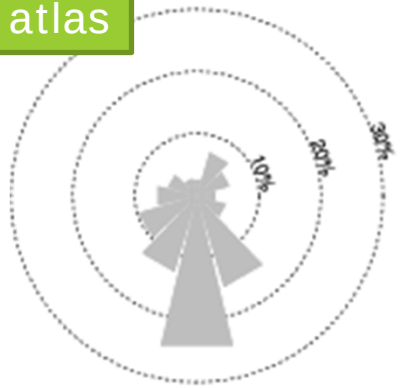


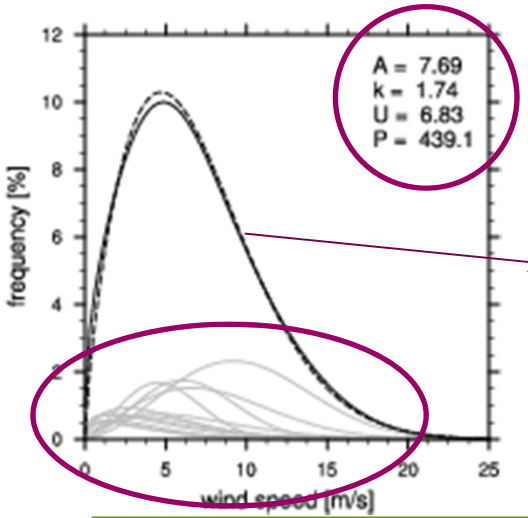
Observed versus numerical wind atlas at 3 sites
h=100 meters, z0=0.03 m
October 2010-September 2013

Example: WASA site 1, far northwest

File = WM01.lib
z0 = 0.03 m h= 100 m

Observed wind atlas

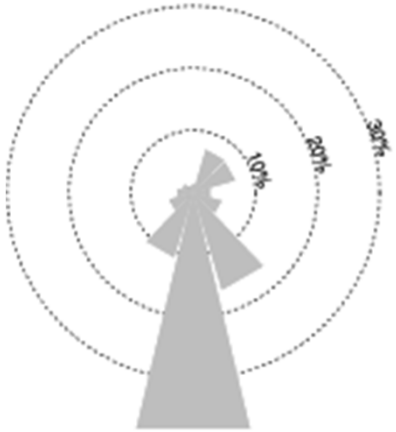


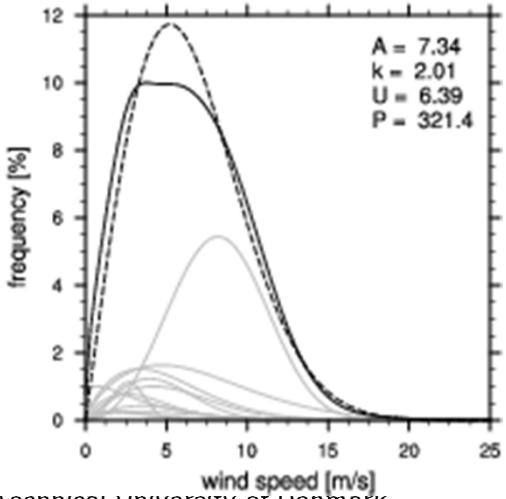


Weighted (solid)
Re-fit (dashed)

Numerical wind atlas KAMM

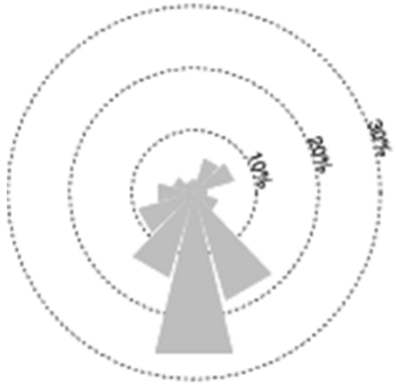
WM01.4_5.lib

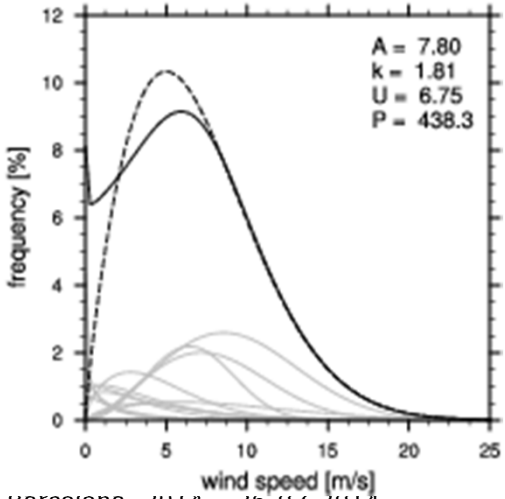




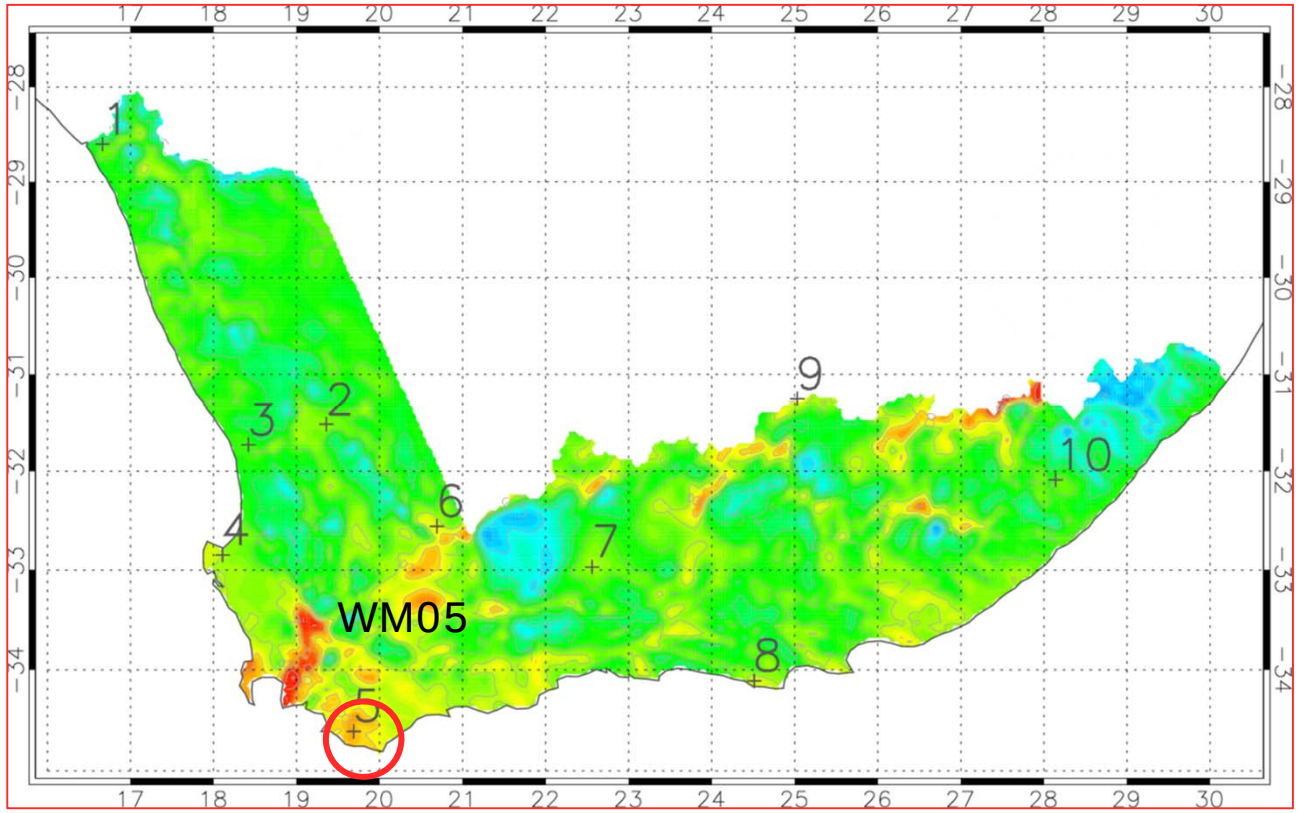
Numerical wind atlas WRF

m_WM01.lib





Comparison at specific sites

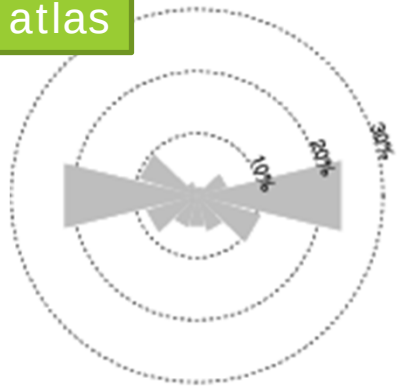


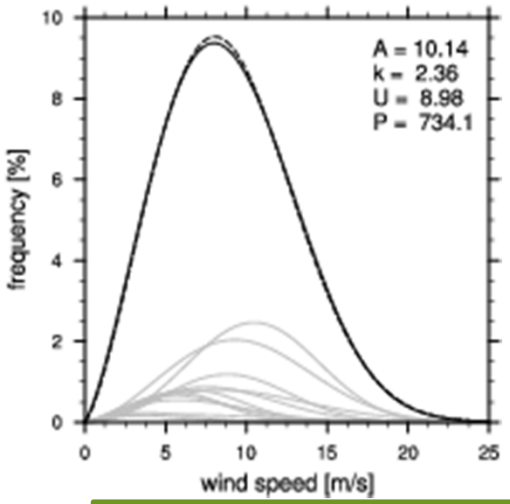
Observed versus numerical wind atlas at 3 sites
h=100 meters, z0=0.03 m
October 2010-September 2013

Example: WM05, southern coast

File = WM05.lib
z0 = 0.03 m h= 100 m

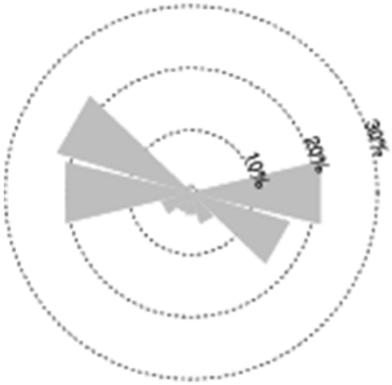
Observed wind atlas

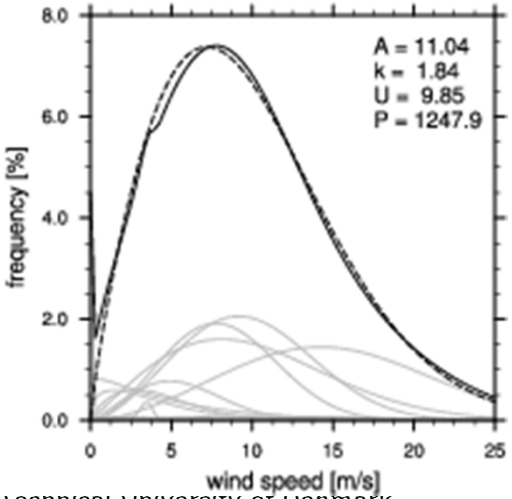




Numerical wind atlas KAMM

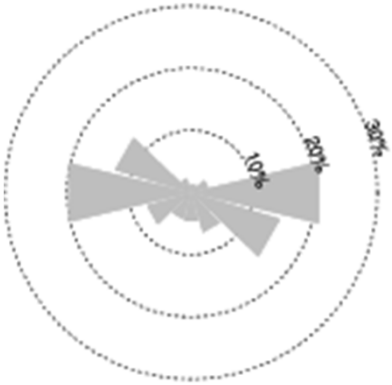
VM05.4_5.lib

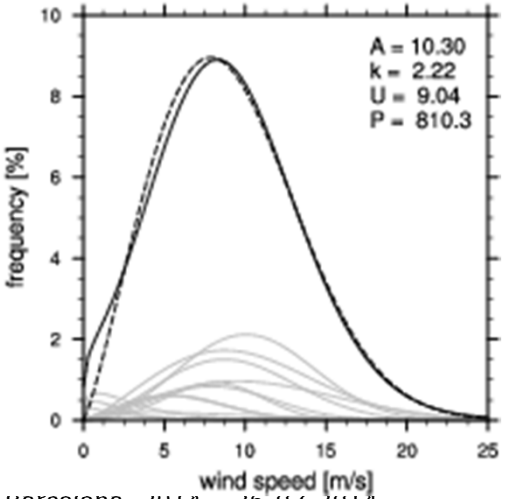




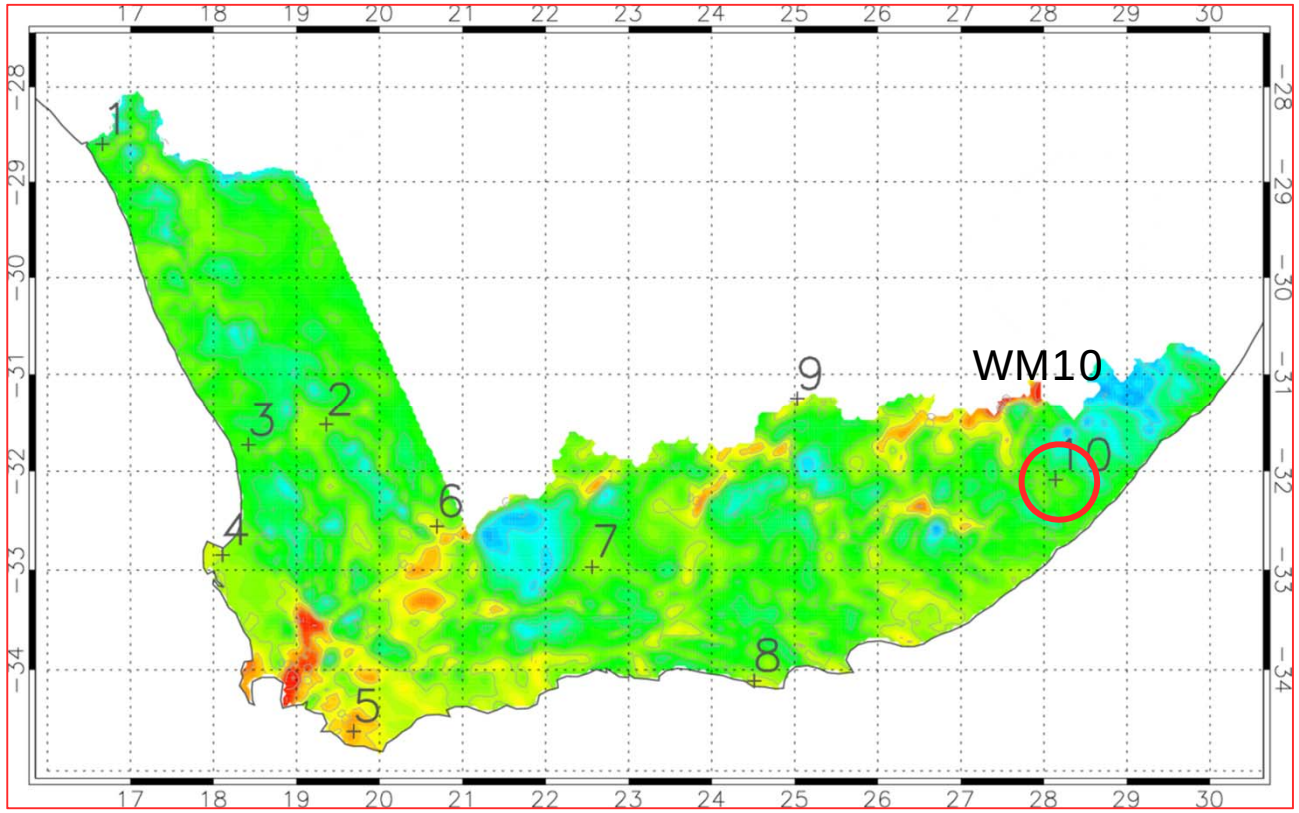
Numerical wind atlas WRF

m_WM05.lib





Comparison at specific sites

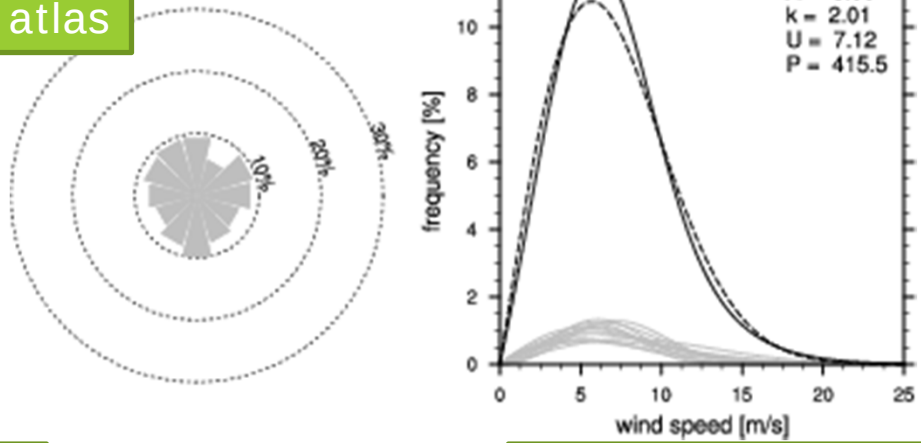


Observed versus numerical wind atlas at 3 sites
h=100 meters, z0=0.03 m
October 2010-September 2013

Example: WM10, Eastern cape

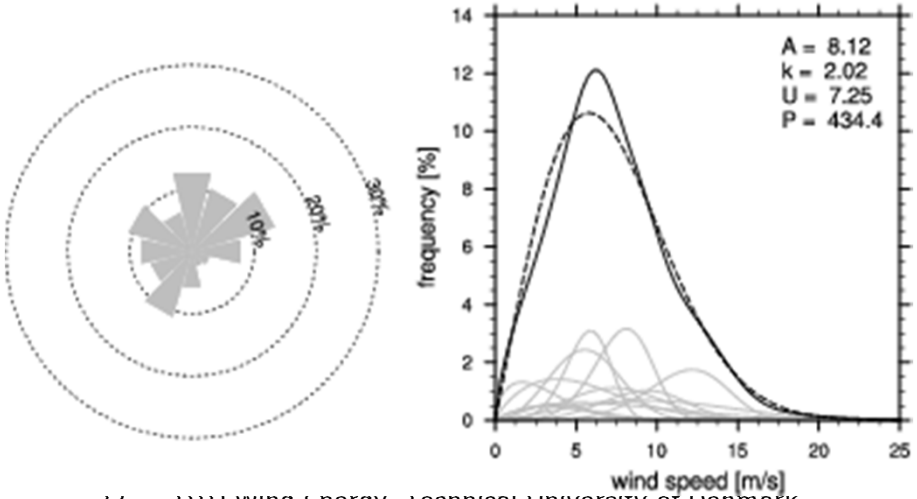
File = WM10.lib
z0 = 0.03 m h= 100 m

Observed wind atlas



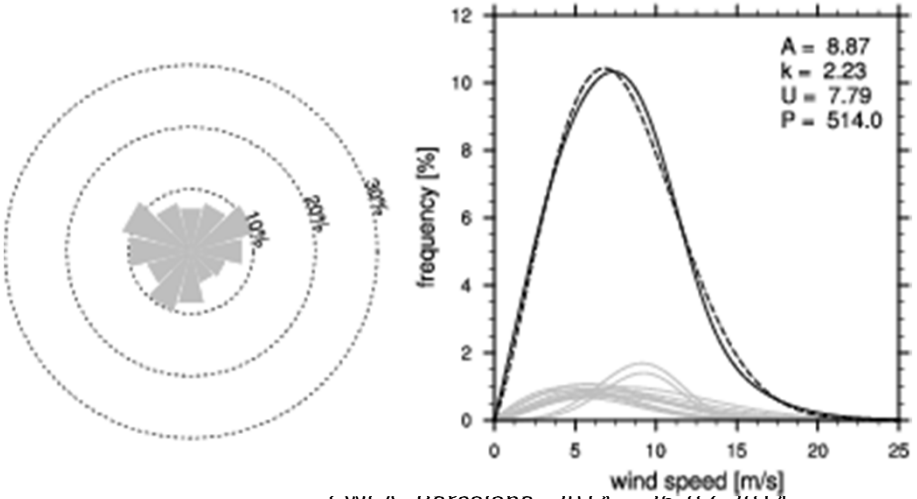
Numerical wind atlas KAMM

VM10.4_5.lib



Numerical wind atlas WRF

m_WM10.lib



Summary and conclusions

- Results from two verified numerical wind atlas for South Africa are presented

- KAMM/WAsP method, numerically very cheap, gives good results
  - underestimation of mean wind speed at most sites; specially at sites influenced by thermal processes
  - resulted in a quite conservative wind resource atlas

- WRF method, numerically very expensive, gives excellent results
  - Stability conditions should be taken into account at generalization
  - Stability conditions should be taken into account when applying WRF-derived wind atlas – where should this come from? How to verify?
  - New dimension to numerical wind atlases

Acknowledgements

The Wind Atlas for South Africa (WASA) project is an initiative of the South African Government - Department of Energy (DoE) and the project is co-funded by

- UNDP-GEF through South African Wind Energy Programme (SAWEP)
- Royal Danish Embassy

WASA Project Steering Committee:

DoE (chair), DEA, DST, UNDP, Danish Embassy, SANEDI